Mining 103

Smelting & Refining
1870's – 1940's

The third of the "Mining for Modelers" clinic series

“Mining for Modelers” Clinics

- Mining 101: Underground Mining
- Mining 102: Transportation and Milling
- Mining 103: Smelting of Ores
  - Examples from Ag-Pb-Zn, Fe, Au, 1870’s – 1940’s

Smelting Overview

- Receive concentrate from a mill, or high grade ores from a mine
  - Metal content generally 30% to 60%
    - Smelting: producing a metallic material from a mineral
      - Typical product = 98% to 99% purity. Not ready for fabrication purposes
    - Refining: further processing that produces a very high purity material ready to be fabricated
      - Gold, silver, copper: 99.99%
- Smelting applies a heating process
  - Drive off sulfur, reduce oxides to metallic form
  - Melt and pour into transportable or useable shape
    - Gold, silver into “dore” bars
    - Copper, lead, zinc, tin into ingots
    - Iron into pig iron or “hot metal”
    - Not alloyed until final step before fabrication
    - Produces product better than 95% ‘pure’

Smelter Furnaces

- Large structures
- ‘Batch’ or continuous ‘campaign’ operations
- Sulfide ores generate ‘exothermic’ reaction
  - Started by charcoal or coke fire, once hot enough is self sustaining
    - Needs oxygen and more feed
- Oxide ores are ‘endothermic’: require constant fuel addition
  - Charcoal, coke, gas, etc.
- Both are continuous feed
- Tap metal, then tap slag
- Gases and dust drawn off up the “stack”
  - *Huge* pollution source
- Slag dumped away from smelter
- “Matte” metal (>95% pure) sent by rail to refinery
  - Silver, gold may be refined on site.

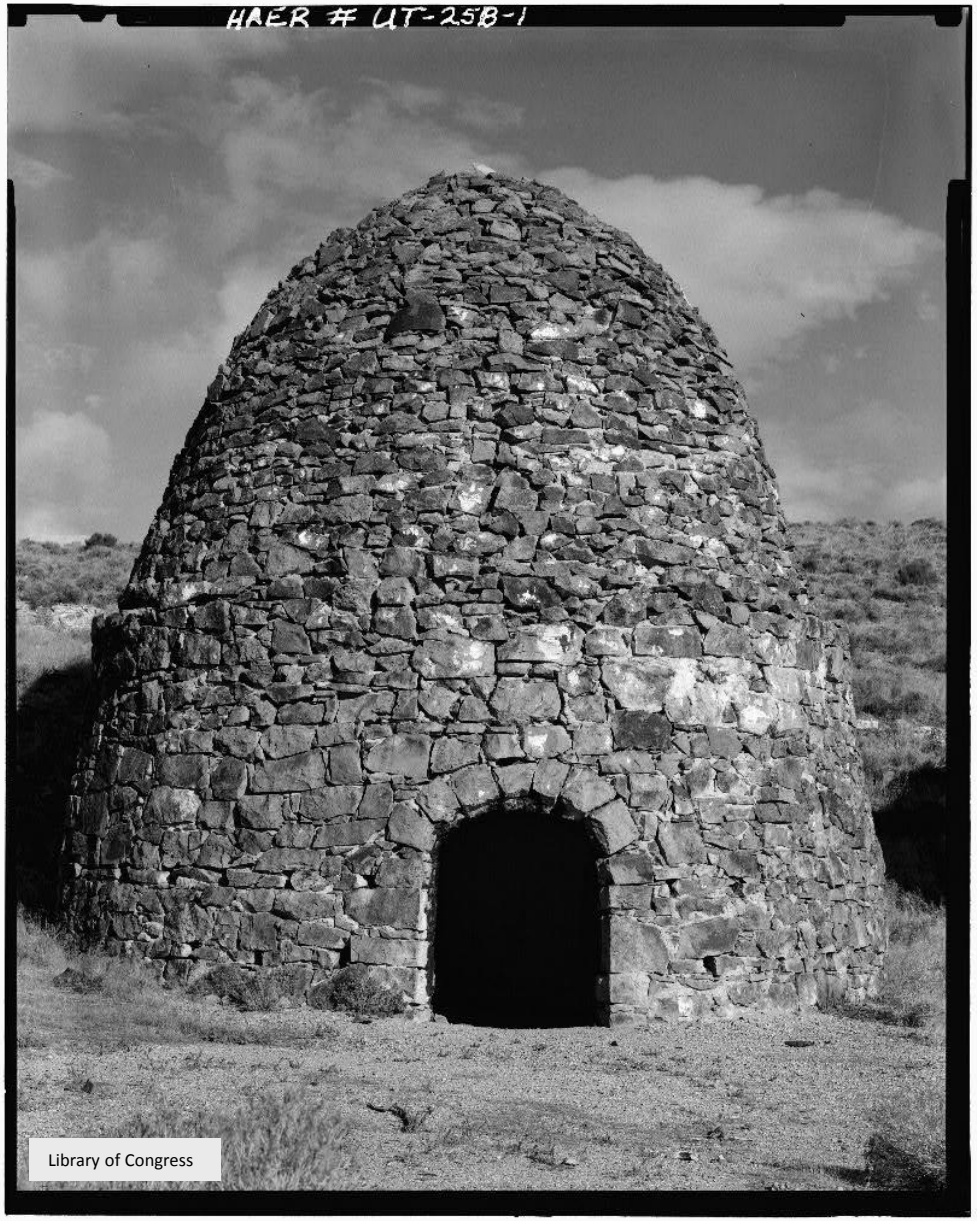
Smelter furnace types

- “Reverberatory” furnaces (copper)
  - Long, low, wide
  - Feed and fuel in one end
    - Air/oxygen not “forced” in under pressure, only drawn in or blown by fans
  - Sloped floor
  - Metal out bottom at far end
- “Blast” type furnace
  - Tall and narrow
  - Feed and fuel in at top
  - Air blast (pressurized) from bottom
  - Metal out bottom
- In both types, slag floats on metal. Metal drawn off, then slag.
  - Must leave some slag to protect furnace bottom

Smelter Fuel: Charcoal (early)

- Warren King Charcoal kilns, Lemhi Co. Idaho

Beehive Charcoal Kilns, Frisco, Utah



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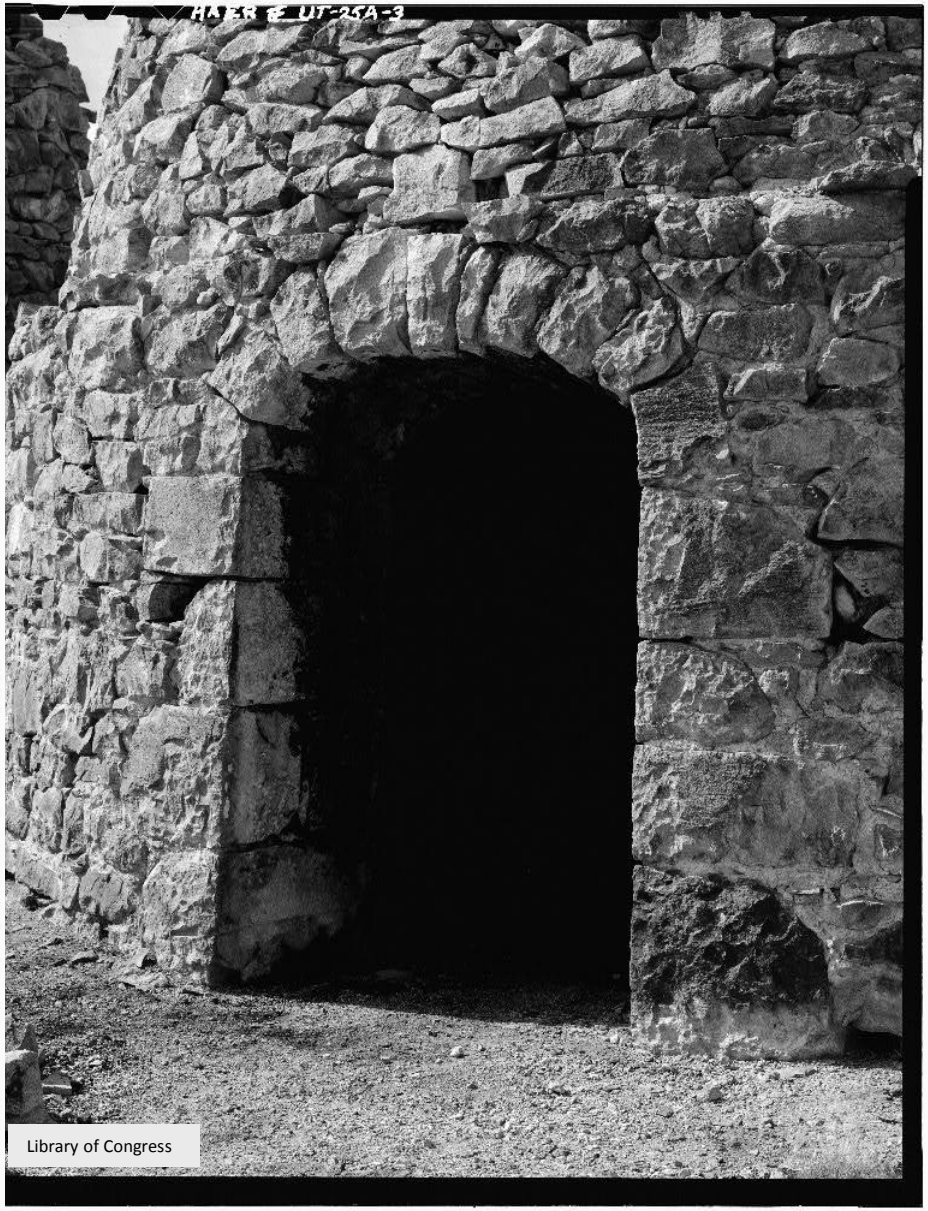

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Smelter sizes through time

- Dibbins Smelter, 1868, Georgetown, Colo.

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Rosita, Colorado, 1880's

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Socorro, N. M., 1900's

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Alma, Colorado, 1907

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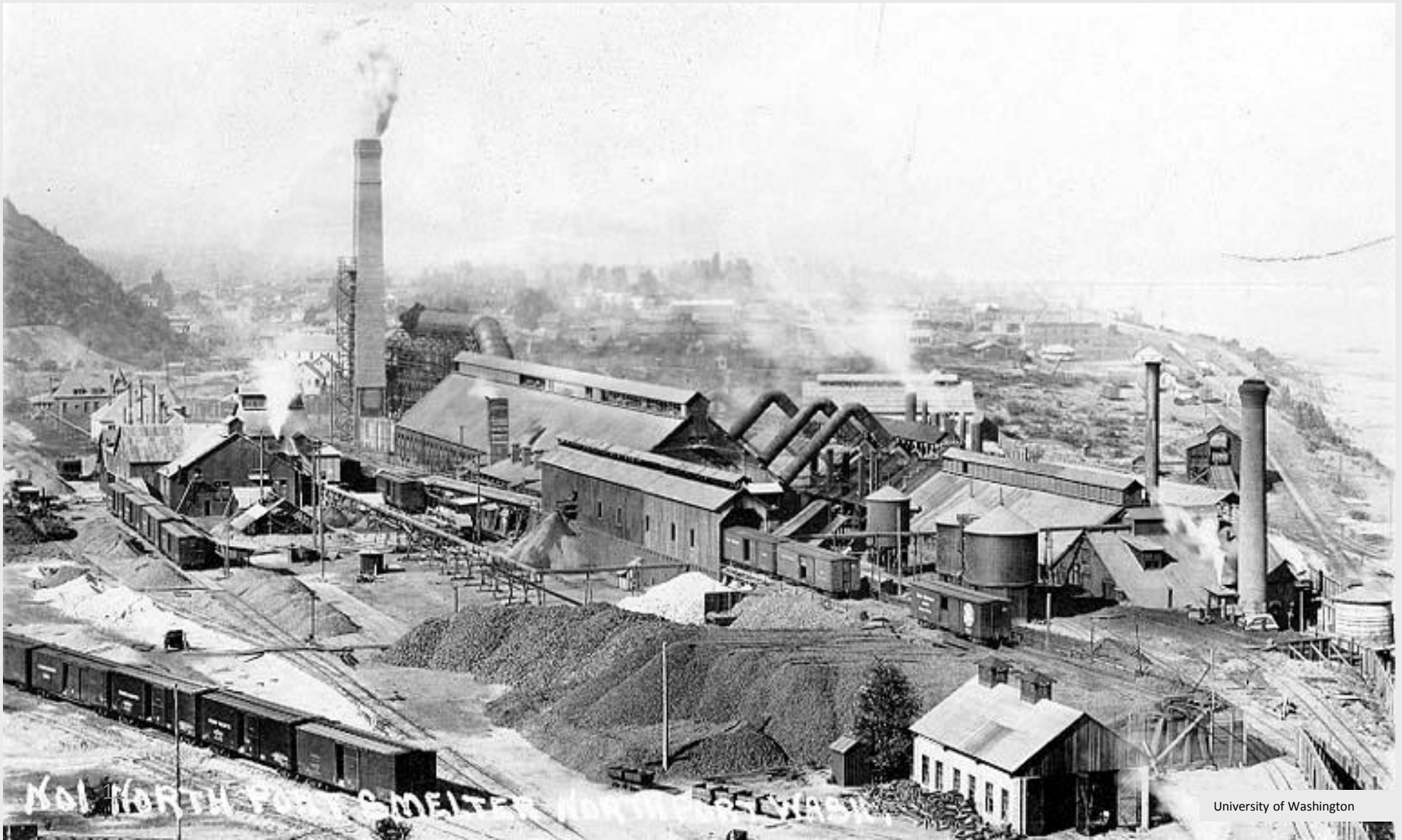
North Port, Washington, 1910



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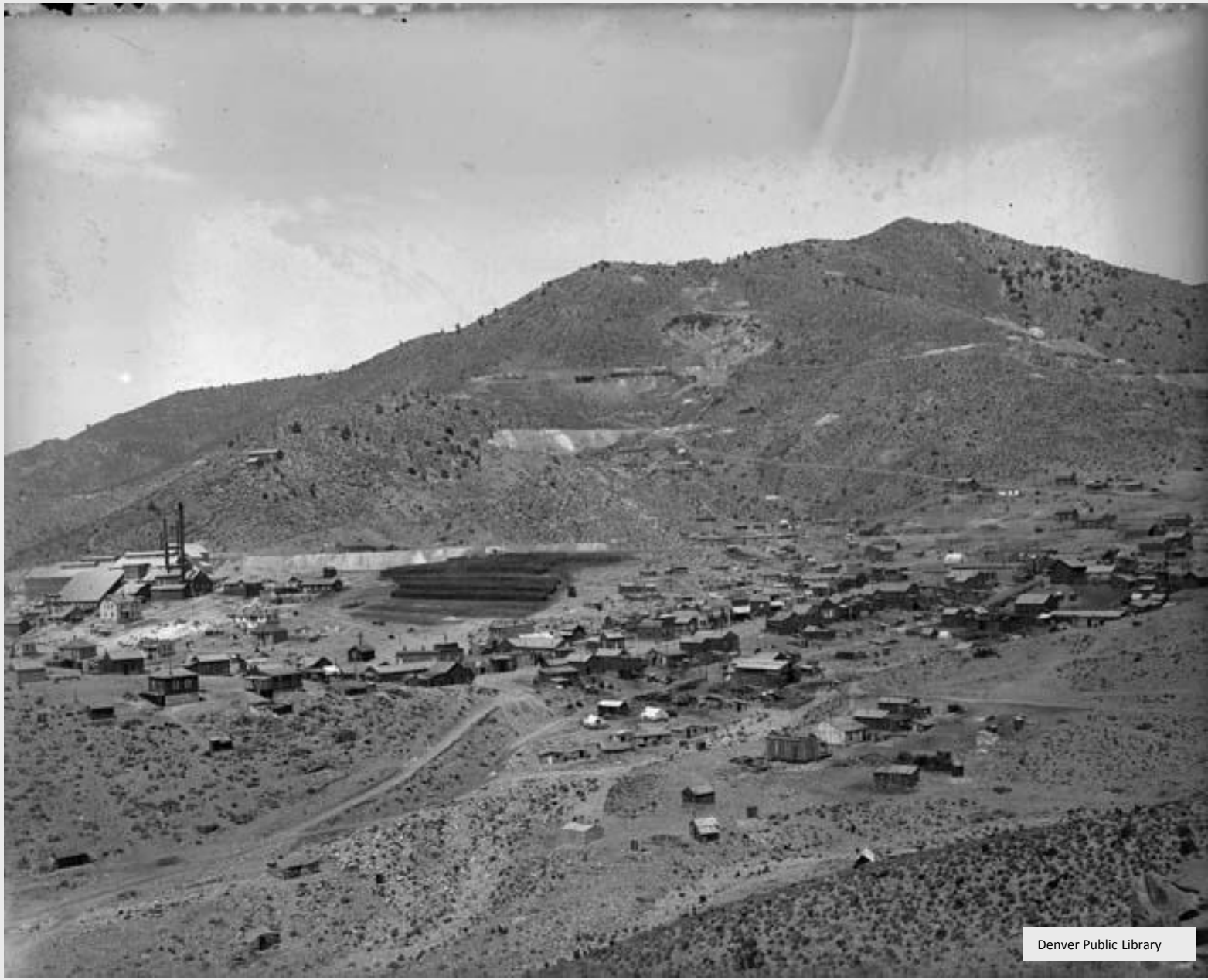
Smelter & town site, Arizona or New Mexico



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Receiving Concentrate or Ore

- Ores & concentrate arrive by rail, stored in bins or in open
  - ASARCO Pueblo, Colo., 1900's

Receiving ores & concentrates, ASARCO, Murray, Ut, 1913

Receiving concentrates,

ASARCO Garfield, Utah, 1942

Receiving Concentrate or Ore

- Tooele, Utah, 1930's

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Smelter Construction, Furnace Hall, 1890’

- Large gallery for several lead ‘blast’ furnaces, Ohio & Colorado Smelter, Salida, 1900

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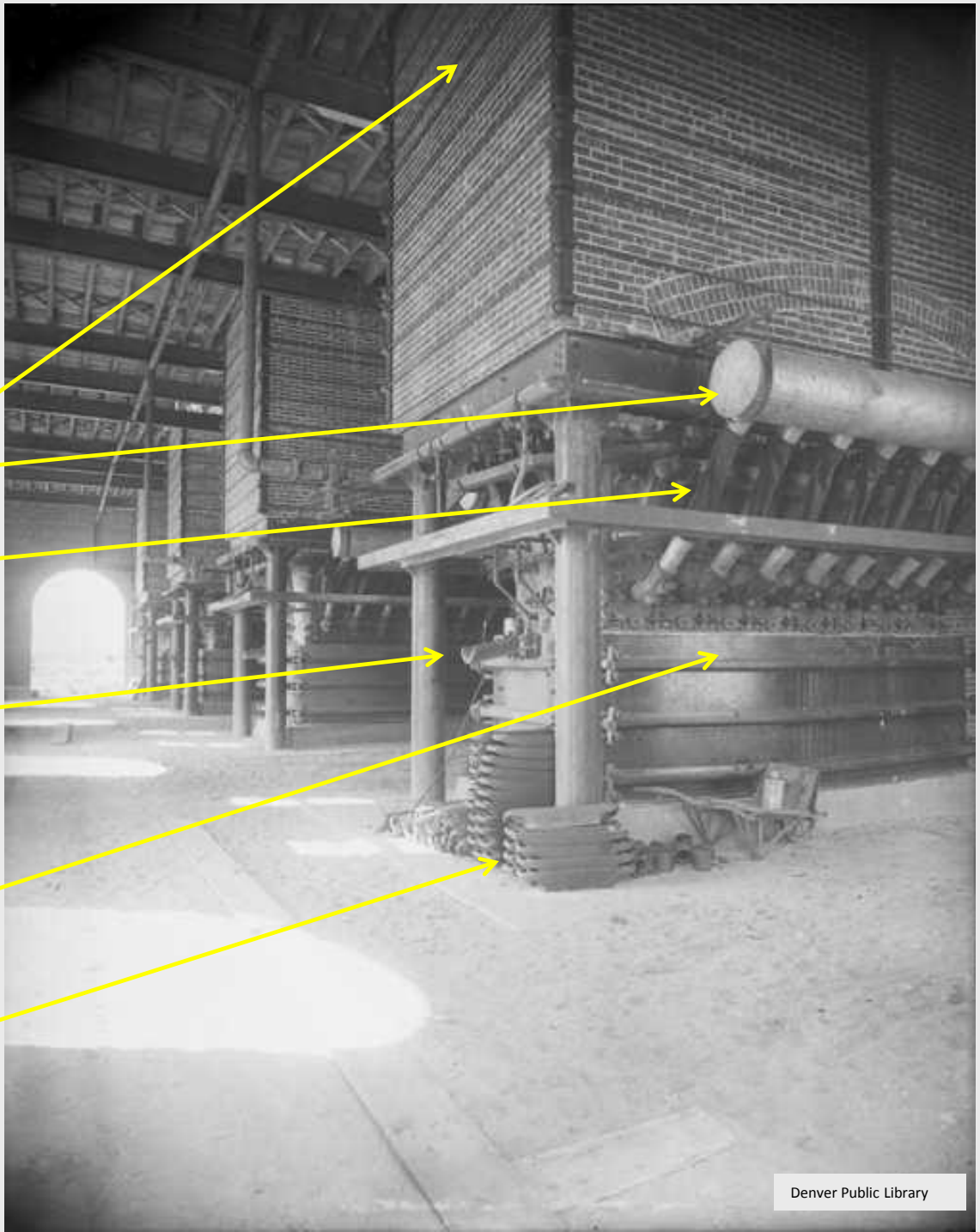
Ohio & Colorado Smelter 'blast' furnaces

- Ore, concentrate, flux continuously added to top
- "Bustle pipe" blows oxidizing air into furnace through 'tuyures' to promote rapid oxidation of sulfide minerals
- Slag and metal tap
  - Slag floats on metal, draw down meta, then slag
- Bed zone for molten metal
- Gases drawn out flue and up stack
- Ingot molds and cart



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Tapping a blast furnace

- Slag pot ready on left, pouring ingots into ingot ‘wheel’ to right

Slag Dump (manual)

- Leadville, 1880's

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Slag transport, Omaha-Grant Smelter, Denver

1900 (l), then 1903 (r)

Slag Dump, Wabuska Smelter, Nevada (Ely??)

Final Product - Silver

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Modern Copper Smelting & Refining

ca. 1940’s – 1950’s

Copper Smelting & Refining, basic steps

Smelting:

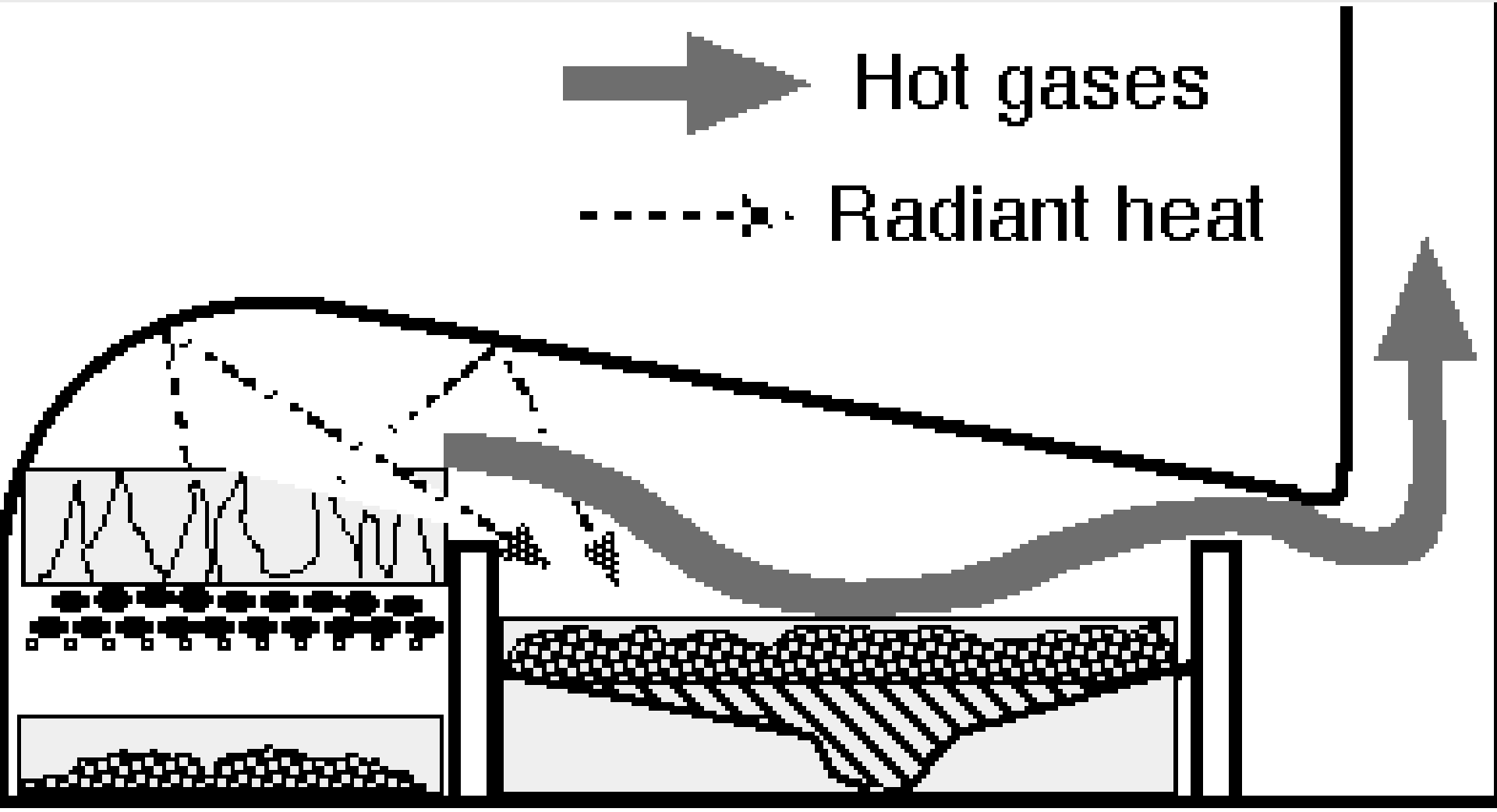
1. Smelter receives concentrates from mills
2. Smelter produces “matte” or “blister” copper
    1. Matte or blister copper is metallic, >75% Cu, with impurities
    2. Slag is discarded
3. Matte or blister copper is “converted” into high purity copper, >98%
4. Smelter casts “anodes” of ‘converted’ copper
5. Anodes sent to refinery for purification by ‘electro-refining’ process

Copper Smelting & Refining, basic steps

Refining

1. Electro-refining consists of:
    1. Suspending anodes in sulfuric acid
    2. Passing HUGE amounts of electricity between anodes and cathodes
        1. 1 amp per square *inch* of cathode surface at low voltage
        2. Anodes usually 3” x 4”, must count both sides
    3. Copper dissolves out of anode and plates atomically onto cathode starter sheet
        1. Cathode typically plates out 170 – 180 pounds of copper
        2. Impurities settle to bottom as sludge.
            1. Will have precious metal and other valuable materials.
    4. Pure (99.9999%) sheet copper is stripped off cathodes
    5. Cathode sheets then melted and cast into ingots for fabrication

Reverberatory Furnace – gives “blister” or “matte” copper for convertor



Copper “converters”

- ‘Blister’ or ‘matte’ copper poured into converter
  - Bars may be remelted then poured into converter
- Oxygen then injected into converter to ‘burn off’ impurities. (Similar to Bessemer converter in steel process)

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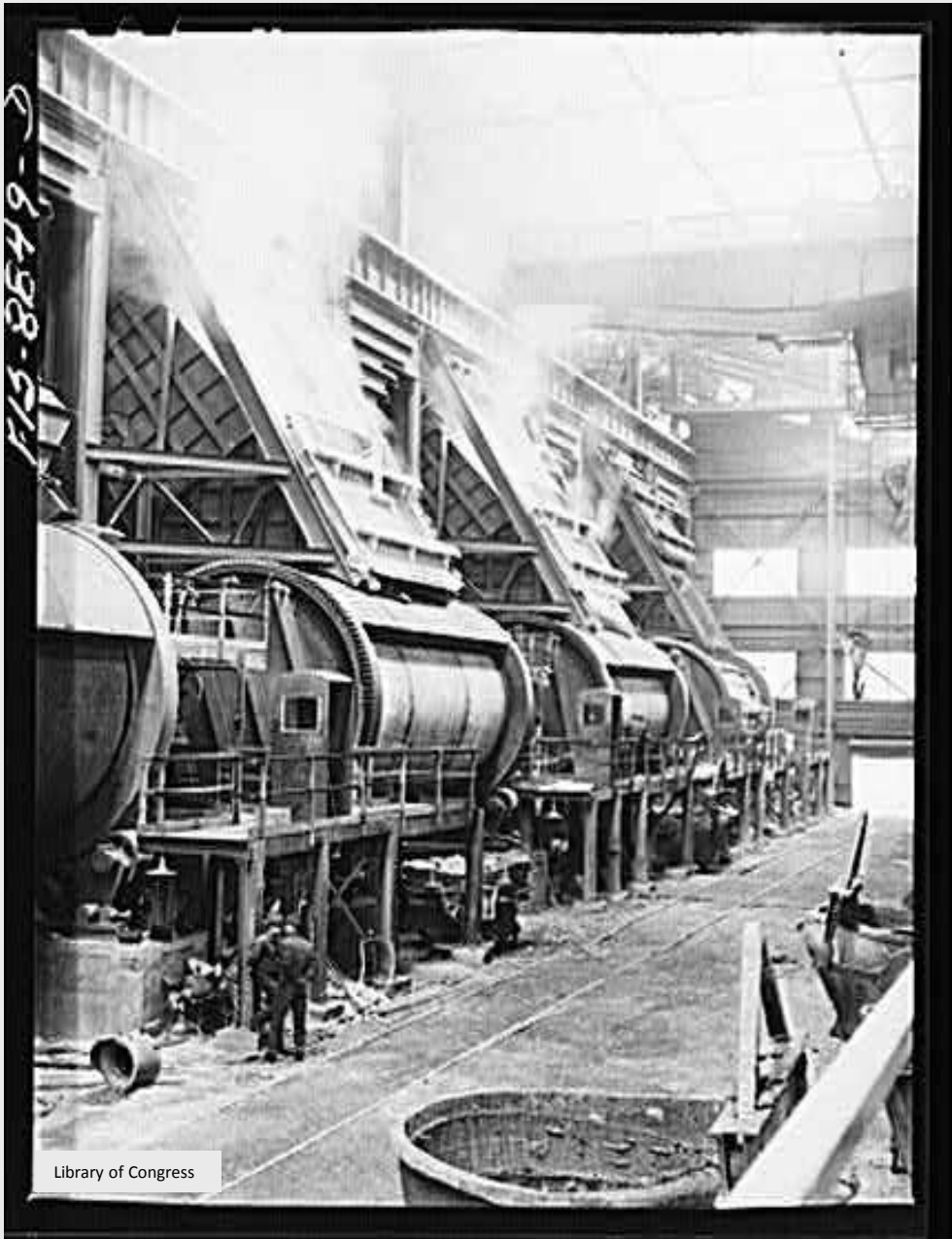
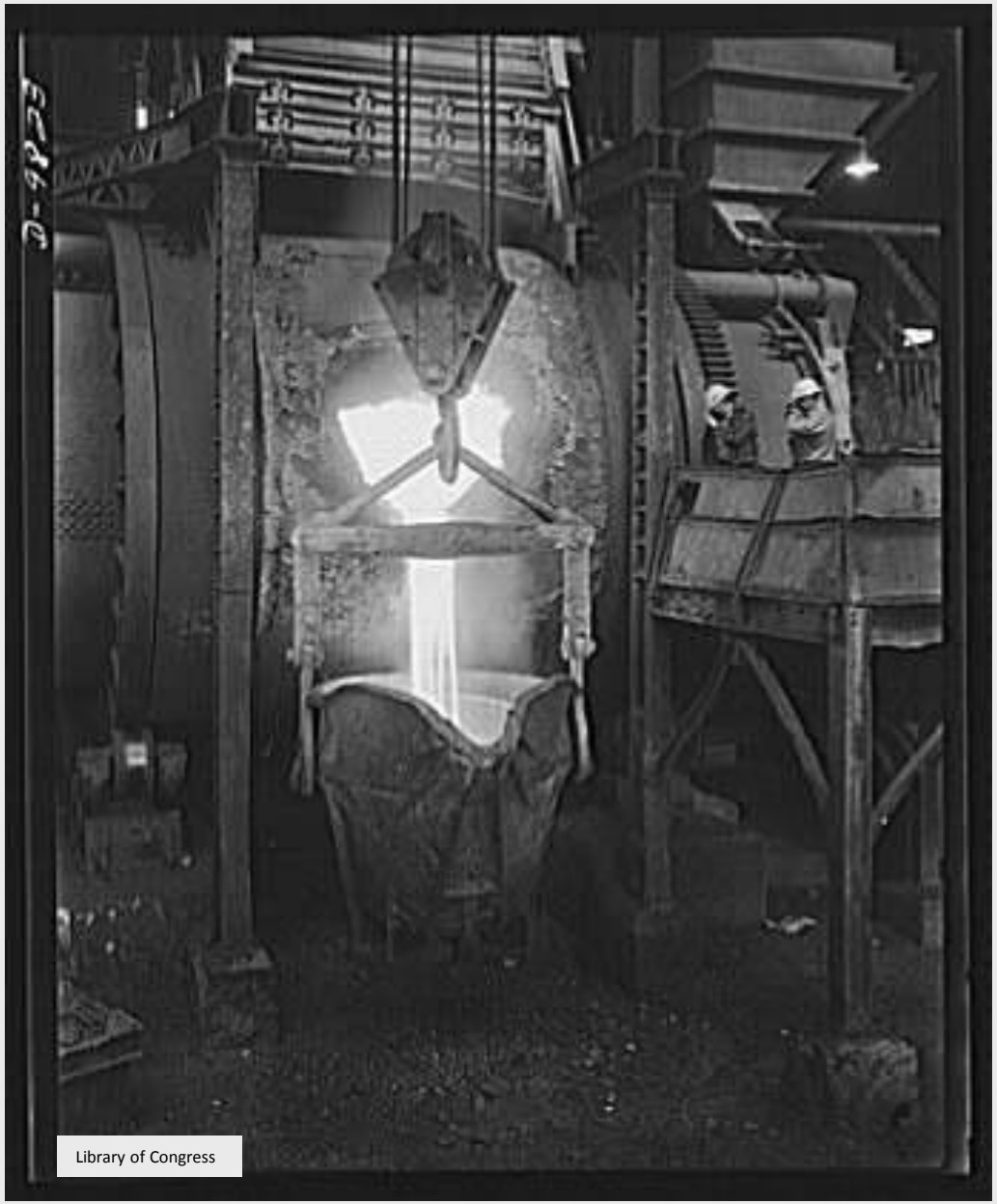
Converter aisle, Anaconda Smelter, Montana, 1942

- “Battery” of four rotary copper converters



Converter Pour

- Poured converter copper will now go to an anode casting station
- May be poured into bricks or bars for other customers.



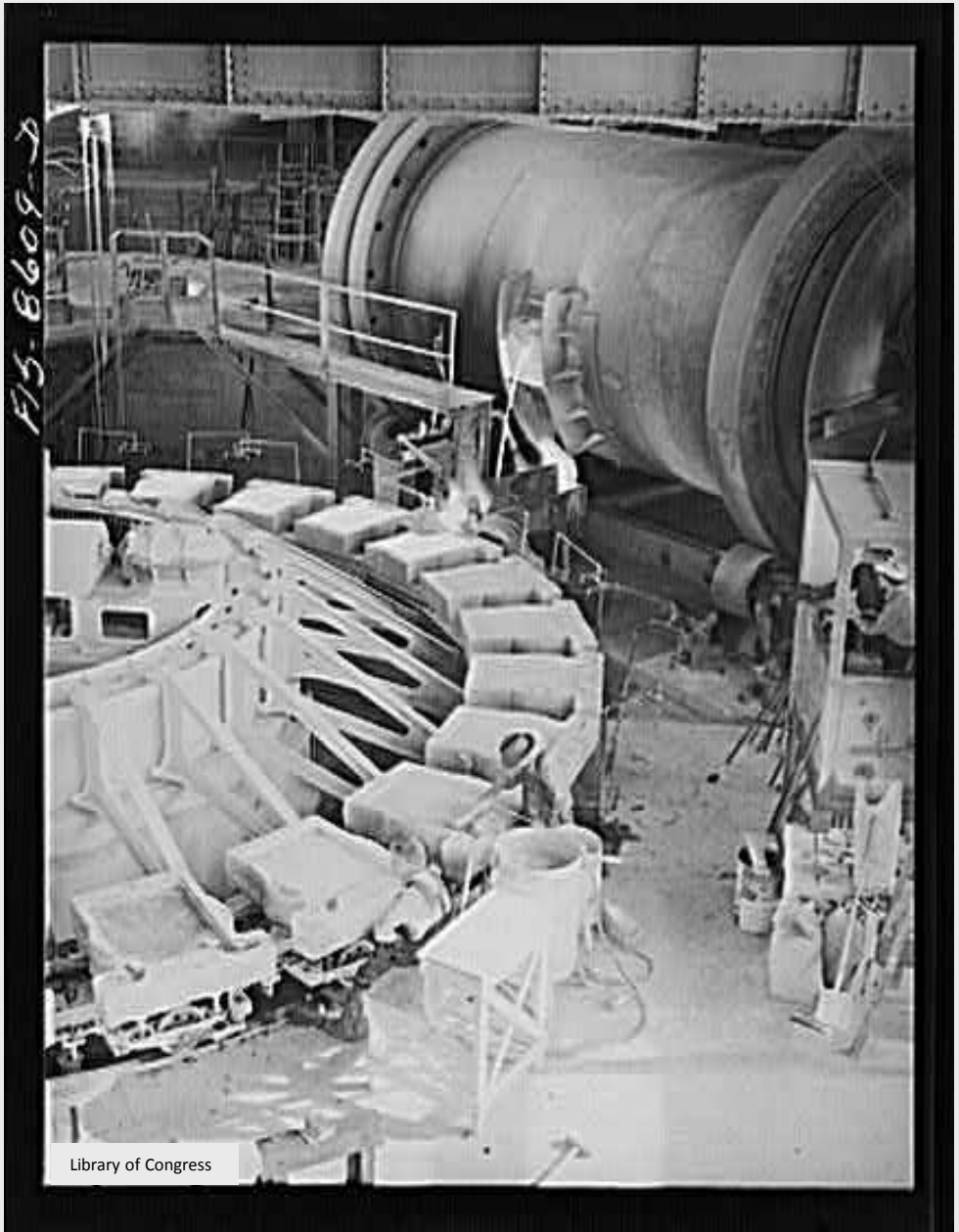
Smelter production styles

- Various bricks and bars stockpiled
- Depends on customer requirements
- Will be remelted for further refining as needed

Anode Casting

- Anaconda, Mont.

- Casting anodes direct from copper converter
  - Anodes are “tee shirt” shaped flat forms, +/- 700 pounds each
  - 3’ x 4’ x 2” to 4” thick
    - (~5500 amps)
- Casting wheel here rotates CCW



Trimming and inspecting cast anodes before shipping to refinery

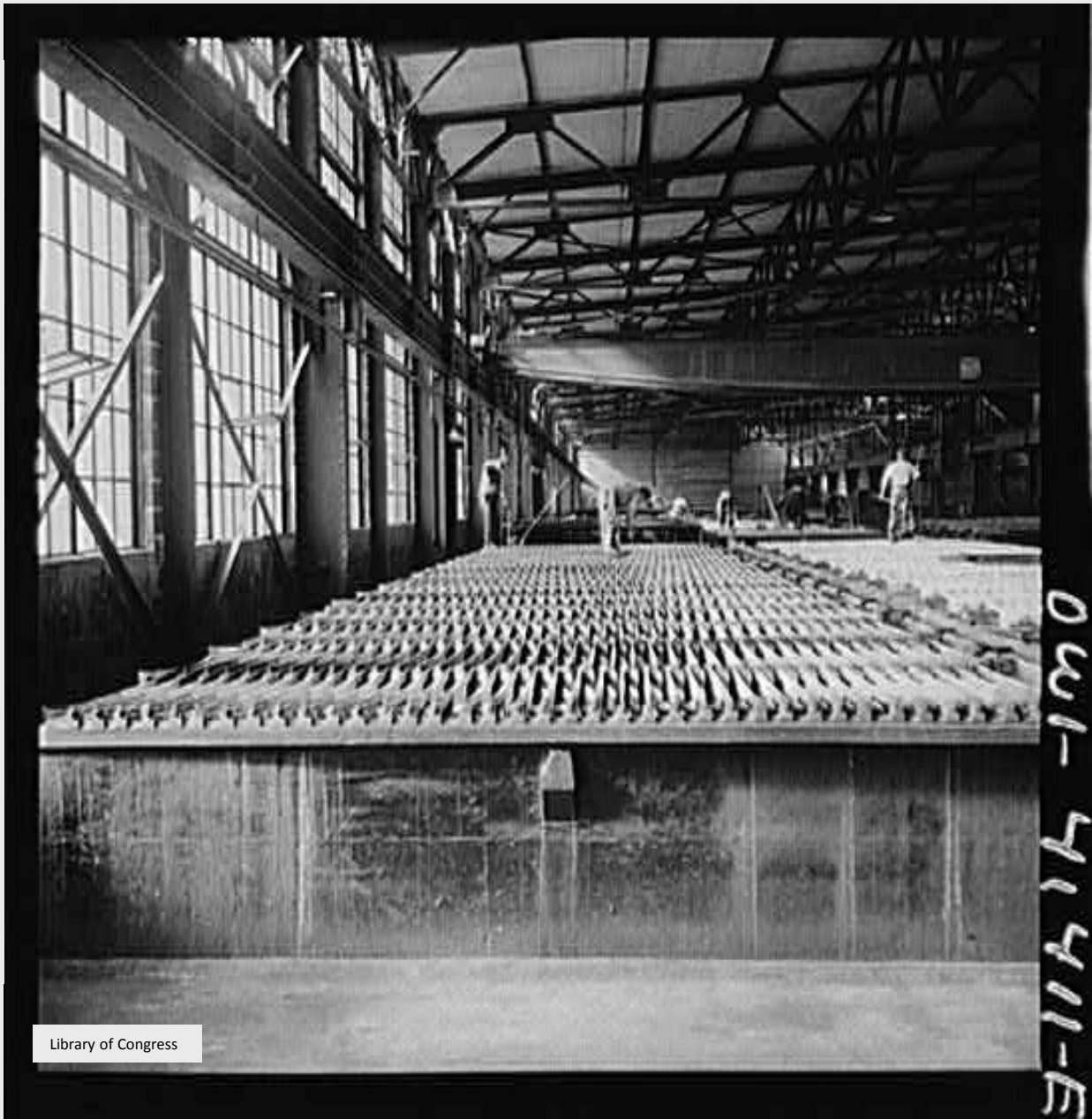
Copper anodes ready for preloading and placement into electro-refining tanks

Anode “conveyor train”

- Anodes in racks for placement in electro-refining tanks

Electro-refining tanks

- Copper “anodes” alternate w/ stainless steel “cathodes”
- Everything submerged in sulfuric acid bath
- Electricity flows from “buss bars” (on 1 edge of tank) through anode
- Copper atoms transported through sulfuric acid, plates onto SS cathode



Electro-refining tanks

- Refinery's may have acres of tanks
- Produce 1,000's of TONS of copper daily
- Cathodes are high purity, 99.99%+, copper
- Cathode copper is what gets made into things
  - Wire, cable, sheets, roofing, jewelry, etc.

Stripping cathodes

- Pure copper sheets are stripped off stainless steel cathode ‘starters’
- Sheets may be sent to refinery for melting into easily transportable ingots, or whatever the customer requires.

Charging copper cathode sheets for remelt

- Cathode sheets loaded into remelt furnace
- Fluxes added
- Ingots or other useable shapes poured

Pure ingots are poured

- Continuous caster (not visible, lower right) fills ingot molds.
- Ingots solidify
- Ingots deluged with water to cool

Ingots inspected and trimmed for shipment

- Remove sharp edges

Finished ingots, stacked and ready for market

- Pure copper ingots for electric wire, plumbing, roofing, etc.

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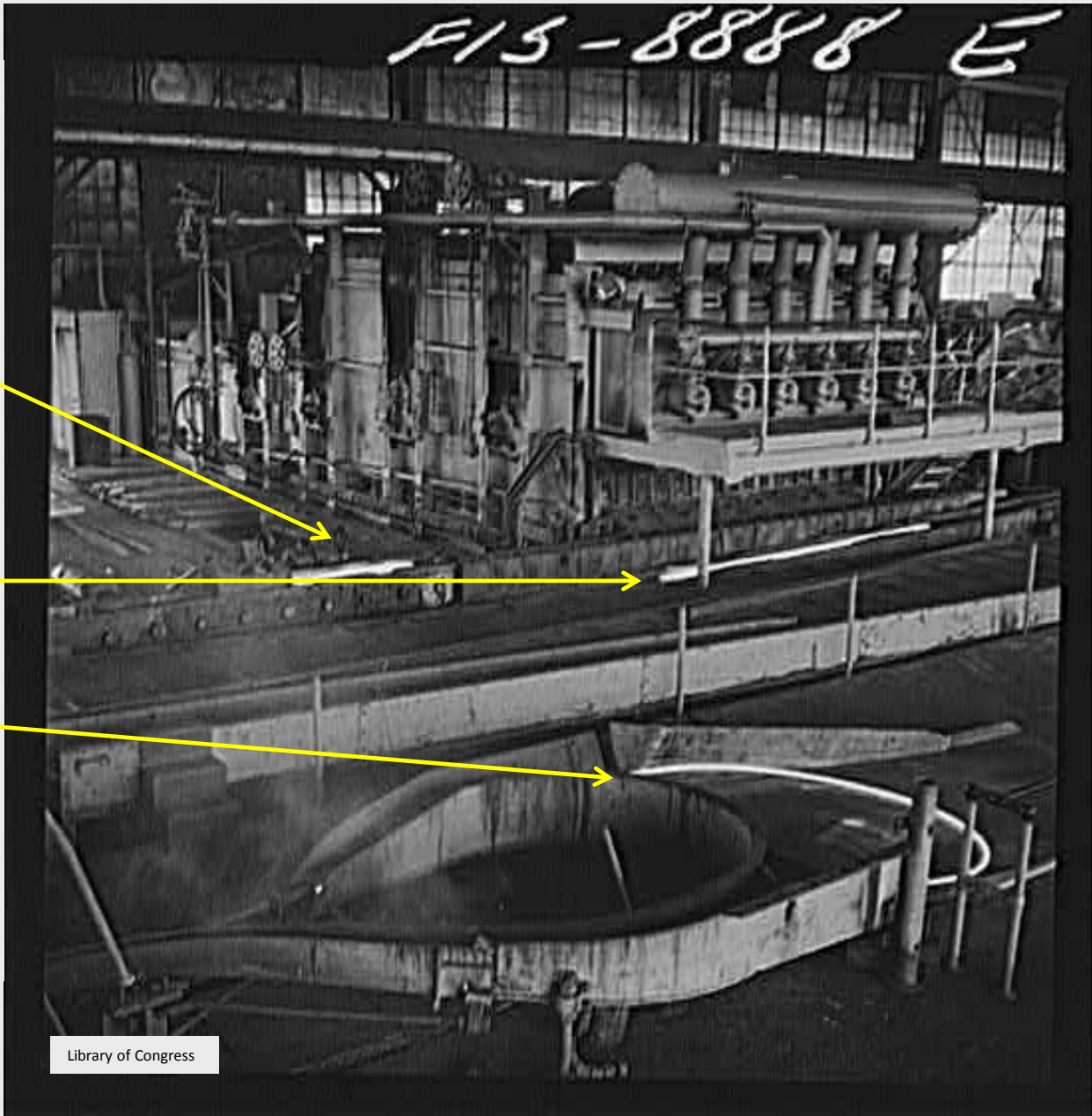
Copper rod production

- Copper ingot being formed into copper rod
- White (hot) ingot squeezed repeatedly into thick copper rod
- Thick copper rod continues being squeezed into thin copper rod for transport to wire mill
- Rods go on to wire production



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- Questions
- Discussion

- Thank you!